Electronic Supplementary Material (ESI) for Environmental Science: Processes & Impacts.

Supplementary Information

Summation of Disinfection By-product CHO Cell Relative Toxicity Indices: Sampling Bias, Uncertainty, and a Path Forward

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6 figures

7 tables

18 pages

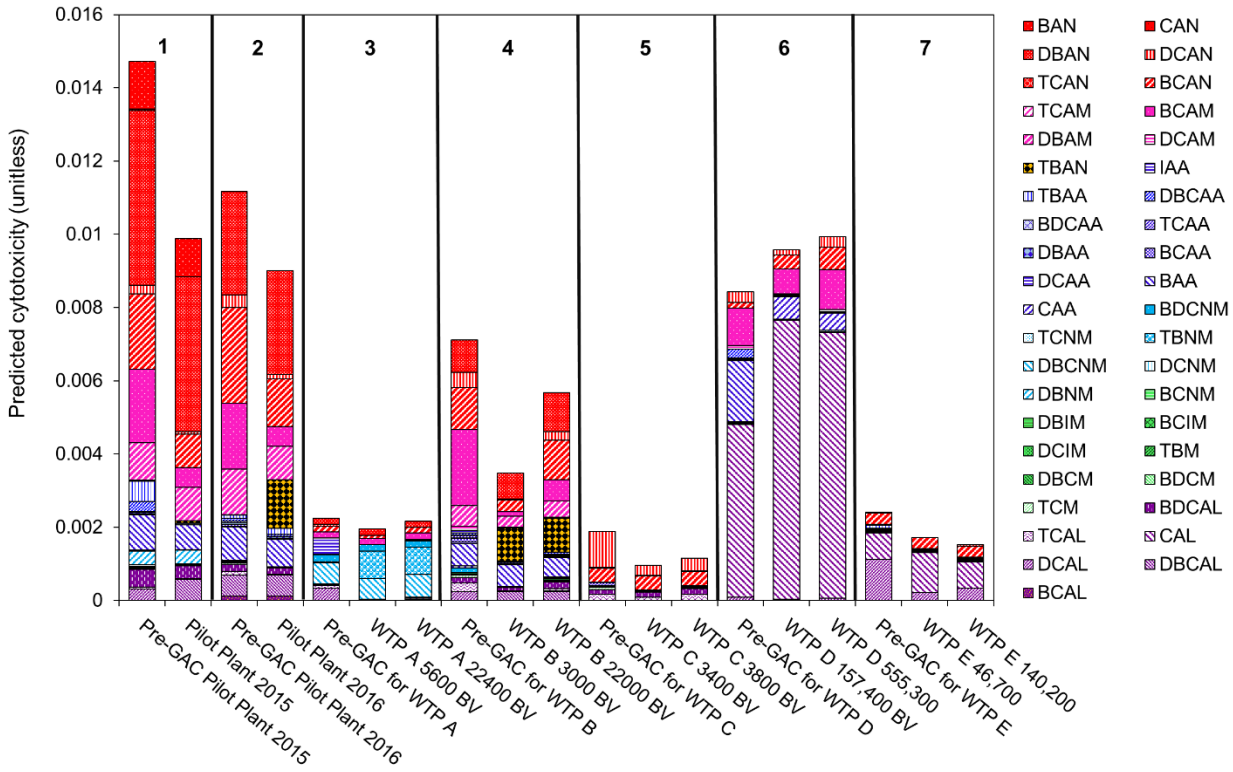

Figure S1 Components of predicted cytotoxicity for data from Stanford *et al.*[1] and Cuthbertson *et al.*[2] Red/pink compounds are HANs and HAcAms. Left-most bar in each panel is pre-GAC predicted cytotoxicity, other bars are GAC effluent samples. Only 41 DBPs are shown, rather than the 70 that were measured, because 29 DBPs were not detected.

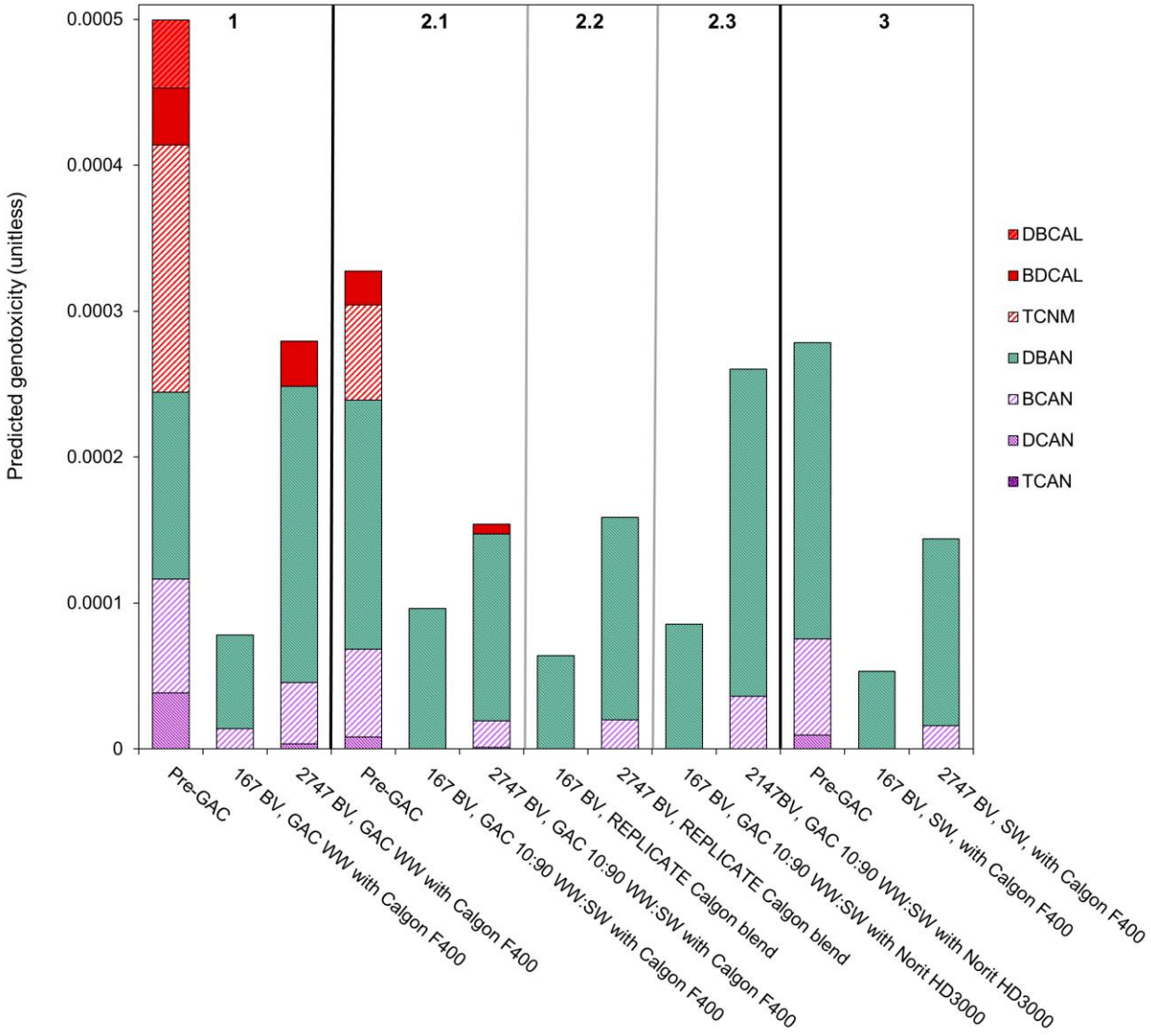

Figure S2 DBP components of predicted genotoxicity for Krasner *et al*.[3] data. Red compounds are measured HALs and TCNM. Left-most bar in each panel is pre-GAC genotoxicity, other bars are post-GAC.

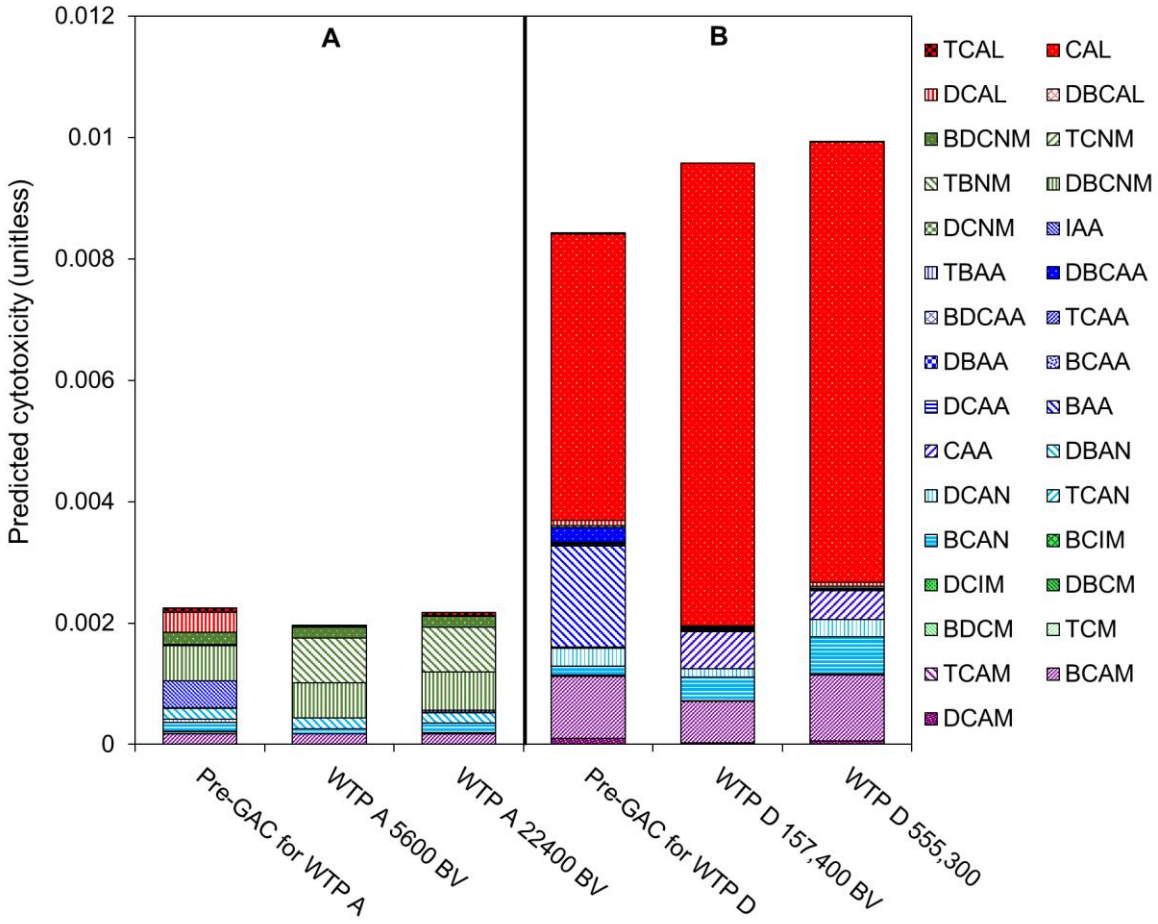

Figure S3 DBP components of predicted cytotoxicity for data from Stanford *et al.*[1] and Cuthbertson *et al.*[2] Red compounds are measured HALs.[1,4] Left-most bar in each panel is pre-GAC predicted cytotoxicity, other bars are GAC effluent samples. Only 41 DBP's are listed (rather than 70 as previously mentioned) because DBPs not detected in a sample are not included.

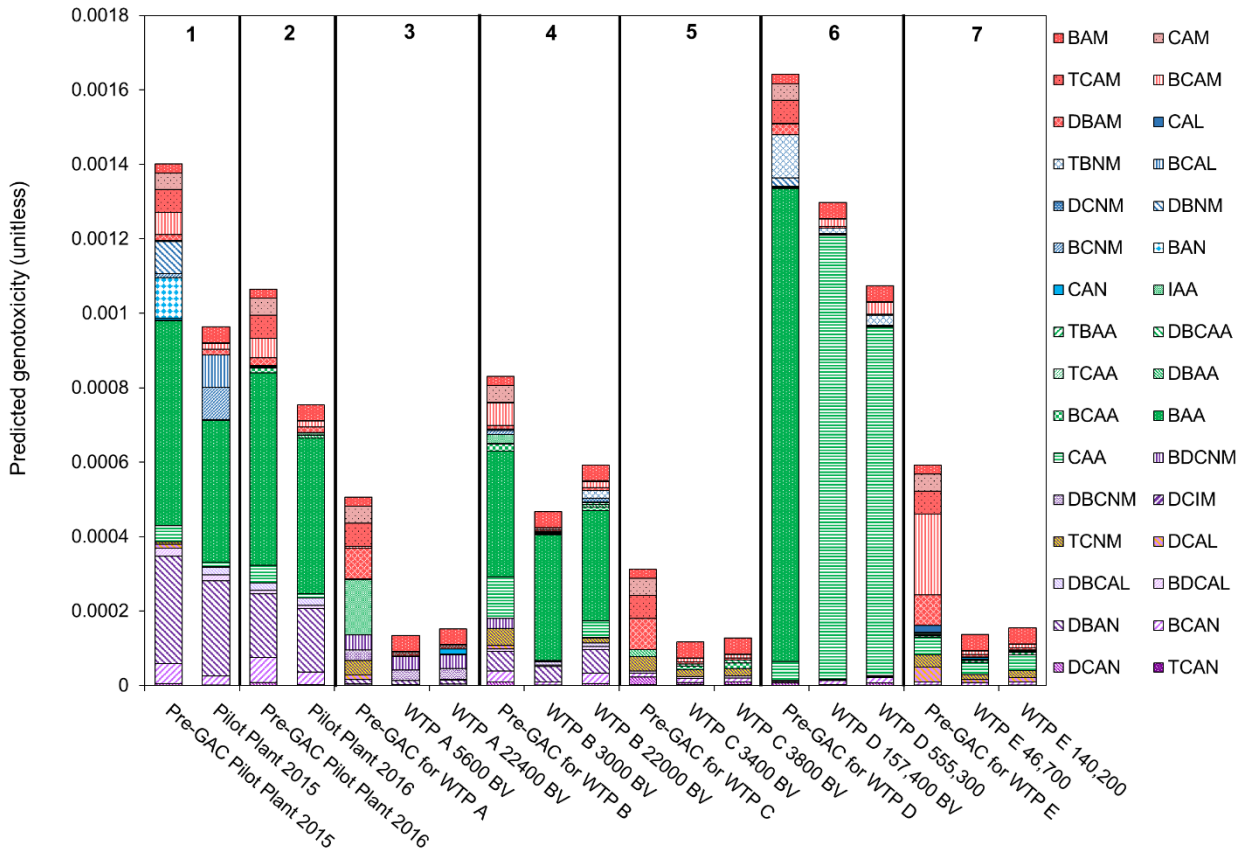

Figure S4 Components of predicted genotoxicity for data from Stanford *et al.* and Cuthbertson *et al.* Red colored compounds are either measured HAcAms from the study or supplemented HAcAms derived from the mean concentrations at 18 WTPs (Table 1).[1,4] Left-most bar in each panel is pre-GAC predicted genotoxicity, other bars are GAC effluent samples. Only 41 DBPs are shown, rather than the 70 that were measured, because 29 DBPs were not detected.

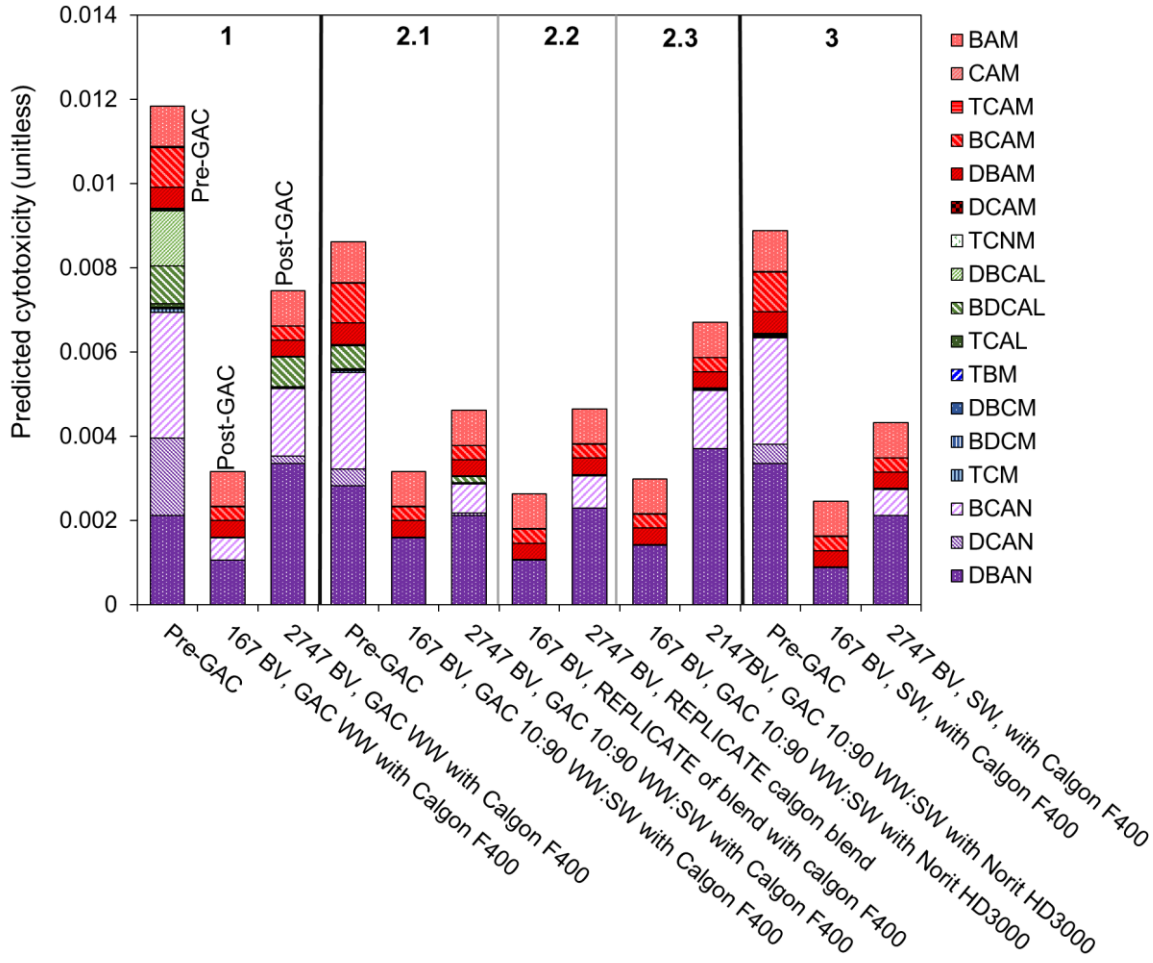

Figure S5 DBP components of predicted cytotoxicity for Krasner *et al.*[3] data. Red compounds are either measured HAcAms from the study or assumed HAcAms (see Table 1). Left-most bar in each panel is pre-GAC cytotoxicity, other bars are post-GAC.

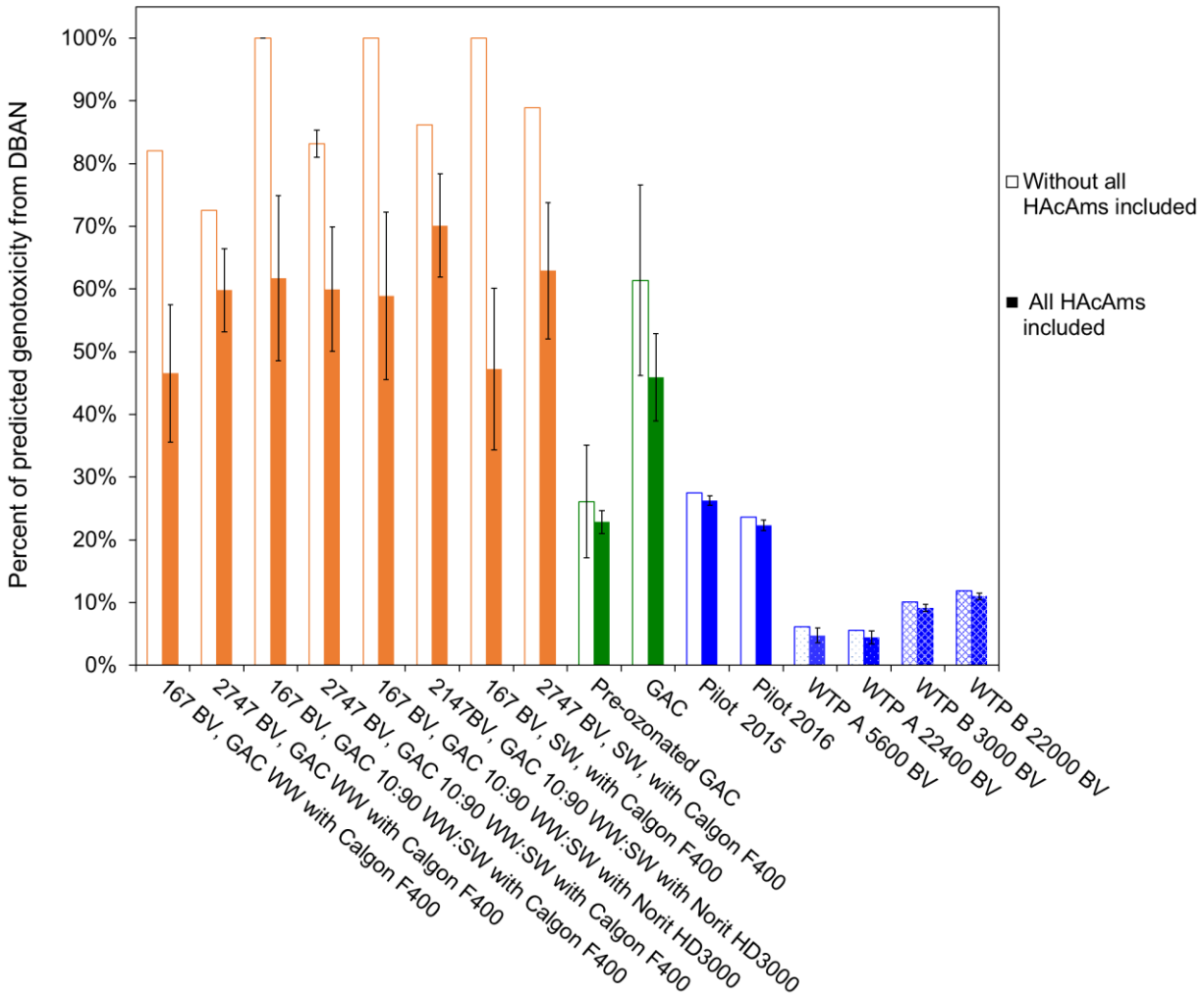

Figure S6 Percent of post-GAC predicted genotoxicity from DBAN without HAcAms (original data) or with addition of assumed HAcAms (data averaged from Kosaka *et al.*[4] as well as DCAM, DBAM, BCAM, and TCAM data from Stanford *et al.*[1] Orange data is from Krasner *et al.*,[3] green data is from McKie *et al.*,[5] and blue data is Stanford *et al.*[1] Data from Stanford *et al.*[1] initially included some HAcAms and therefore the filled bars only include assumed concentrations for the additional HAcAms. Stanford *et al.*[1] (blue bars) have different pattern fills because each data set included different HAcAms – The pilots included DCAM, DBAM, and BCAM, WTP A included DCAM and BCAM, and WTP B included DCAM, DBAM, BCAM, and TCAM. McKie *et al*.[5] did not measure DBAN and thus the average, post-GAC DBAN concentrations from Krasner *et al.*[3] and Stanford *et al.*[1] were included. Error bars for data including HAcAms (filled bars) are derived from the standard deviation of HAcAm data from Kosaka *et al*.[4] and the HAcAms that Stanford *et al.*[1] measured (DCAM, DBAM, BCAM, TCAM). Error bars for data without HAcAms (open bars) are derived from data included in the original publications.

Table S1 Toxic potencies derived from Wagner and Plewa[6] (TBAN cytotoxicity from a personal correspondence[7])

Abbreviation	Compound's full name	Genotoxic Potency (unitless)	Cytotoxicity potency (unitless)
TCM	Trichloromethane	Not genotoxic	9.62E-03
BDCM	Bromodichloromethane	Not genotoxic	1.15E-02
DBCM	Dibromochloromethane	Not genotoxic	5.36E-03
TBM	Tribromomethane	Not genotoxic	3.96E-03
TCAN	Trichloroacetonitrile	1.01E-3	1.6E-04
DCAN	Dichloroacetonitrile	2.75E-03	5.73E-05
BCAN	Bromochloroacetonitrile	3.24E-04	8.46E-06
DBAN	Dibromoacetonitrile	4.71E-05	2.85E-06
CAN	Chloroacetonitrile	6.01E-04	6.83E-05
BAN	Bromoacetonitrile	3.85E-05	3.21E-06
TBAN	Tribromoacetonitrile	Not genotoxic	2.71E-06
CAL	Chloroacetaldehyde	1.43E-04	3.51E-06
TCAL	Trichloroacetaldehyde	Not genotoxic	1.16E-03
BCAL	bromochloroacetaldehyde	6.21E-04	5.34E-06
BDCAL	Bromodichloroacetaldehyde	4.70E-04	2.04E-05
DBCAL	Dibromochloroacetaldehyde	1.44E-04	5.15E-06
DCAL	Dichloroacetaldehyde	7.95E-04	2.92E-05
DCIM	Dichloroiodomethane	Not genotoxic	4.13E-03
BCIM	Bromochloroiodomethane	Not genotoxic	2.42E-03
DBIM	Dibromoiodomethane	Not genotoxic	1.91E-03
CAA	Chloroacetic acid	4.11E-04	8.10E-04
BAA	Bromoacetic acid	1.7E-05	9.6E-06
IAA	Iodoacetic acid	8.7E-6	2.95E-6
DCAA	Dichloroacetic acid	Not genotoxic	7.30E-03
BCAA	Bromochloroacetic acid	3.64E-03	7.78E-04
DBAA	Dibromoacetic acid	1.76E-03	5.90E-04
TCAA	Trichloroacetic acid	Not genotoxic	2.40E-03
DBCAA	Dibromochloroacetic acid	1.36E-02	2.02E-04
BDCAA	Dromodichloroacetic acid	Not genotoxic	6.85E-04
TBAA	Tribromoacetic acid	2.46E-03	8.50E-05
BDCAA	Bromodichloroacetic acid	Not genotoxic	6.85E-04
DCAM	Dichloroacetamide	Not genotoxic	1.92E-03
DBAM	Dibromoacetamide	7.44E-04	1.22E-05
BCAM	Bromochloroacetamide	5.83E-04	1.71E-05
TCAM	Trichloroacetamide	6.54E-03	2.50E-03
CAM	Chloroacetamide	1.38E-03	1.48E-04
BAM	Bromoacetamide	3.68E-05	1.89E-06

TCNM	Trichloronitromethane	9.34E-05	5.36E-04
DBCNM	Dibromochloronitromethane	1.43E-04	6.88E-06
BDCNM	Bromodichloronitromethane	6.32E-05	1.32E-05
BCNM	Bromochloronitromethane	1.65E-04	4.05E-05
DBNM	Dibromonitromethane	2.62E-05	6.09E-06
DCNM	Dichloronitromethane	4.21E-04	3.73E-04
TBNM	Tribromonitromethane	6.99E-05	8.57E-06

Table S2 GAC and oxidation treatment characteristics.

	Corresponding Figure	Influent water	Pre-GAC oxidant	Post-GAC oxidant
Data from McKie *et al.*[5] and Krasner *et al.*[3] (HAcAMs supplemented to)				
Pre-ozonated GAC	Figure 3, Panels 1-3	Lake	Ozone	Chlorine
GAC	Figure 3, Panels 4-8	River	None	Chlorine
167 BV with Calgon F400	Figure 4	Wastewater	None	Chlorine
2747 BV with Calgon F400	Figure 4	Wastewater	None	Chlorine
167 BV with Calgon F400	Figure 4	10:90 WW:SW	None	Chlorine
2747 BV with Calgon F400	Figure 4	10:90 WW:SW	None	Chlorine
167 BV with Norit HD3000	Figure 4	10:90 WW:SW	None	Chlorine
2147 BV with Norit HD3000	Figure 4	10:90 WW:SW	None	Chlorine
167 BV with Calgon F400	Figure 4	Surface water	None	Chlorine
2747 BV with Calgon F400	Figure 4	Surface water	None	Chlorine
Stanford *et al.*[1] and Cuthbertson *et al.*[2] (DCAM, DBAM, BCAM, TCAM aggregated from. CAM and BAM supplemented to)				
Pilot plant 2015	Figures 1 & 2, Panel 1	UF membrane permeate from surface water treatment plant	None	Chlorine
Pilot plant 2016	Figures 1 & 2, Panel 2	Tertiary filtered ww	None	Chlorine
WTP A	Figures 1 & 2, Panel 3	Lake	Chlorine	Chlorine
WTP B	Figures 1 & 2, Panel 4	River	KMnO4	Chlorine
WTP C	Figures 1 & 2, Panel 5	Reservoir	NaMnO4	Chlorine
WTP D	Figures 1 & 2, Panel 6	River	KMnO4, chloramine	Chloramine
WTP E	Figures 1 & 2, Panel 7	River	Chloramine	Chloramine
HAcAm data from Kosaka *et al.*[4] (HACAMs aggregated from)				
Event 1, WTP 5	Figures 2, 3, 4	Surface water	None	Chlorine
Event 2, WTP 5	Figures 2, 3, 4	Surface water	None	Chlorine
Event 1, WTP 10	Figures 2, 3, 4	Surface water	Ozone	Chlorine

Event 2, WTP 10	Figures 2, 3, 4	Surface water	Ozone	Chlorine
Event 1, WTP 12	Figures 2, 3, 4	Surface water	Ozone	Chlorine
Event 2, WTP 12	Figures 2, 3, 4	Surface water	Ozone	Chlorine

Table S3 Aggregated HAcAm data from Kosaka *et al*.[4]

Pre-GAC HAcAm concentrations (M)							
		[DCAM]	**[DBAM]**	**[BCAM]**	**[TCAM]**	**[CAM]**	**[BAM]**
Event 1	WPP 5	2.58E-08	7.84E-09	2.26E-08	6.16E-09	7.49E-09	4.35E-09
Event 2	WPP 5	1.80E-08	5.99E-09	1.57E-08	4.93E-09	5.35E-09	2.90E-09
Event 2	WPP10	1.09E-08	4.61E-10	4.06E-09	2.46E-09	2.14E-09	7.25E-10
Event 2	WPP10	9.38E-09	9.22E-10	4.06E-09	2.46E-09	2.14E-09	7.25E-10
Event 1	WPP12	4.69E-09	2.31E-09	4.64E-09	6.16E-10	1.07E-09	7.25E-10
Event 2	WPP12	4.69E-09	3.23E-09	5.80E-09	1.23E-09	2.14E-09	1.45E-09
Column Avg:		1.22E-08	3.46E-09	9.47E-09	2.98E-09	3.39E-09	1.81E-09
Post-GAC HAcAm concentrations (M)							
		[DCAM]	**[DBAM]**	**[BCAM]**	**[TCAM]**	**[CAM]**	**[BAM]**
Event 1	WPP 5	2.34E-09	2.77E-09	2.90E-09	6.16E-10	2.14E-09	2.17E-09
Event 2	WPP 5	2.34E-09	1.38E-09	1.74E-09	6.16E-10	1.07E-09	7.25E-10
Event 2	WPP10	1.56E-09	1.38E-09	2.32E-09	6.16E-10	2.14E-09	7.25E-10
Event 2	WPP10	1.56E-09	4.61E-10	1.16E-09	6.16E-10	1.07E-09	7.25E-10
Event 1	WPP12	1.56E-09	4.61E-09	2.32E-09	6.16E-10	1.07E-09	3.62E-09
Event 2	WPP12	7.82E-10	5.07E-09	2.32E-09	6.16E-10	1.07E-09	1.45E-09
Column Avg:		1.69E-09	2.61E-09	2.13E-09	6.16E-10	1.43E-09	1.57E-09

Table S4 DBAN concentrations from Krasner *et al*.[3] and Stanford *et al.*[1] The average was used for McKie *et al*.

Source	Water Source	DBAN (nM)
Stanford *et al.*[1]	WW	12.07
	UF Permeate	8.05
	Lake	0.50
	Lake	0.50
	River	2.01
	River	3.02
Krasner *et al*.[3]	100% WW	3.02
	100% WW	9.56
	10:90 WW:SW	4.53
	10:90 WW:SW	6.03
	10:90 WW:SW	3.02
	10:90 WW:SW	6.54
	10:90 WW:SW	4.02
	10:90 WW:SW	10.56
	100% SW	2.51
	100% SW	6.03
Average DBAN (nM)		5.12
Standard deviation		3.39

Table S5 Raw data from Stanford *et al.*[1] measuring post-GAC concentrations of DBPs. Dashes indicate non-detect.

DBP (µg/L)	Pilot 2015	Pilot 2016	WTP A 5,600 BV	WTP A 22,400 BV	WTP B 3,000 BV	WTP B 22,000 BV	WTP C 3,400 BV	WTP C 3,800 BV	WTP D 157,400 BV	WTP D 555,300 BV	WTP E 46,700 BV	WTP E 140,200 BV
TCM	2.2	3.59	6.1	22.5	10.2	30.2	21.9	29.5	16.3	15.5	8.5	8.5
BDCM	12.3	12.55	4.9	9.5	5.9	16.7	1.7	1.8	2.4	2.5	1.3	1.3
DBCM	24.5	25.93	--	--	4	7.3	--	--	0.3	0.4	0.3	0.4
TBM	17.1	--	--	--	0.5	0.4	--	--	--	--	0.5	0.5
TCAN	--	--	--	--	--	--	0.3	0.3	--	--	--	--
DCAN	0.4	0.8	0.0025	0.0025	0.2	1.5	1.8	2.2	0.9	1.8		0.2
BCAN	1.2	1.7	0.1	0.2	0.4	1.4	0.5	0.5	0.5	0.8	0.4	0.4
DBAN	2.4	1.6	0.1	0.1	0.4	0.6	--	--	--	--	--	--
TCAL	0.8	1.9	0.9	7.5	1.1	9.9	16	29.4	--	1.2	0.2	0.3
BDCAL	1.4	0.7	--	--	0.3	0.7	0.5	0.6	--	--	--	--
DBCAL	0.7	0.7	--	--	0.3	0.3	--	--	--	--	--	--
DCAL	0.05	--	0.05	0.05	0.05	0.05	--	--	0.1	0.2	0.7	1.1
TCNM	0.003	--	0.003	0.003	0.003	0.2	0.3	0.3	--	--	0.2	0.3
DCIM	0.4	--	0.006	0.006	0.006	0.006	--	--	--	--	--	--
BCIM	0.5	0.5	0.0195	0.0195	0.0195	0.0195	--	--	--	--	--	--
DBIM	0.6	0.7	--	--	--	--	--	--	--	--	--	--
DBCNM	--	--	1.2	1.3	--	--	--	--	--	--	--	--
BDCNM	--	--	0.8	0.8	0.05	0.05	--	--	--	--	--	--
DCAM	0.8	0.7	0.1	0.2	0.8	4.1	0.3	0.7	7.4	14.3	2.4	2.7
DBAM	2.4	2.4			0.8	1.2	--	--	0.6	0.5	--	--
BCAM	1.6	1.6	0.5	0.5	0.4	1.7	--	--	2	3.2	--	--
TCAM	--	--	--	--	0.4	0.8	0.4	0.5	0.4	0.5	--	--
CAA	0.5	0.423	--	--		1.7	--	--	46.3	36.3	1.3	1.6
BAA	0.9	0.986	--	--	0.8	0.7	--	--	--	--	--	--
DCAA	1.6	1.63	--	4	2.4	12	11.3	18.8	1.6	3.3	6.5	8.2

BCAA	0	3.99	--	--	2.1	4.7	--	--	0.2	--	1.4	1.6
DBAA	5.8	5.18	--	--	1.3	1.4	--	--	0.2	--	--	--
TCAA	0.6	--	--	--	1	7.3	8.6	12.9	3.9	4.3	0.8	2.7
BDCAA	--	1.11	--	--	1.6	3.3	--	--	1.5	1.3	1.2	1.3
DBCAA	--	2.92	--	--	2	2.6	--	--	0.9	0.9	0.8	0.9
TBAA	--	4.28	--	--	--	--	--	--	0.3	--	0.4	0.6
IAA	--	--	0.0025	0.02	0.0025	0.0025	--	--	--	--	0.007	--
CAN	0.004	--	--	--	--	--	--	--	--	--	--	--
BAN	0.4	--	--	--	--	--	--	--	--	--	--	--
TBAN	0.05	1	--	--	0.7	0.7	--	--	--	--	--	--
BCNM	0.012	--	--	--	0.012	0.3	--	--	--	--	--	--
DBNM	0.5	--	--	--			--	--	--	--	--	--
DCNM	0.014	--	--	--	0.014	1.1	--	--	0.8	1.5	0.1	0.1
BCAL	--	.1	--	--	--	--	--	--	--	--	--	--
TBNM	--	--	1.9	1.9	--	--	--	--	--	--	--	--
CAL	--	--	--	--	--	--	--	--	2.1	2	0.3	0.2

Table S6 Raw data from Krasner *et al.*[3] and McKie *et al.*[5] measuring post-GAC concentrations of DBPs. Dashes indicate non-detect.

DBP (µg/L)		Krasner *et al.*[3]									McKie *et al.*[5]							
	167 BV, GAC WW with Calgon F400	2747 BV, GAC WW with Calgon F400	167 BV, GAC 10:90 WW:SW with Calgon F400	167 BV, GAC REPLI-CATE of blend with Calgon F400	2747 BV, REPLI-CATE of 10:90 Calgon	167 BV, GAC 10:90 WW:SW with Norit HD3000	2147BV, GAC 10:90 WW:SW with Norit HD3000	2747 BV, GAC 10:90 WW:SW with Calgon F400	167 BV, SW, with Calgon F400	2747 BV, SW, with Calgon F400	Pre-ozonated GAC			GAC				
TCM	1.8	5.9	1.7	1.4	3.9	1.7	8.6	3.4	0	3.4	13.12	13.3	10.8	164	158.2	63.4	96.4	73.4
BDCM	2.8	9.2	2.8	2.4	7.2	4	17.8	7	2.1	6.8	11.7	13.3	11.8	25.1	3.73	17.8	19.9	19.8
DBCM	4.3	10.8	6.3	4.9	11.4	7.4	21	11.5	4.6	11.3	4.53	6.3	5.09	--	--	--	--	--
TBM	2.7	3.8	4.1	3.4	5.3	3.6	6	4.9	3.4	5.8	--	--	--	--	--	--	--	--
DCAN	--	1.1	--	--	--	--	--	0.4	--	--	Not measured-	Not measured-	Not measured-	Not measured-	Not measured-	Not measured-	Not measured-	Not measured-
BCAN	0.7	2.1	--	--	1	--	1.8	0.9	--	0.8	Not measured-	Not measured-	Not measured-	Not measured-	Not measured-	Not measured-	Not measured-	Not measured-
DBAN	0.6	1.9	0.9	0.6	1.3	0.8	2.1	1.2	0.5	1.2	Not measured-	Not measured-	Not measured-	Not measured-	Not measured-	Not measured-	Not measured-	Not measured-
TCAL	--	2.6	--	--	0.7	--	2.4	0.8	--	0.6	Not measured-	Not measured-	Not measured-	Not measured-	Not measured-	Not measured-	Not measured-	Not measured-
BDCAL	--	2.8	--	--	--	--	--	0.6	--	--	Not measured-	Not measured-	Not measured-	Not measured-	Not measured-	Not measured-	Not measured-	Not measured-
CAA	--	--	--	--	--	--	--	--	--	--	1.47	1.55	3.12	2.66	3.67	0.59	2.05	5.78
BAA	--	--	--	--	--	--	--	--	--	--	0.63	2.87	3.55	--	--	--	--	--
DCAA	--	--	--	--	--	--	--	--	--	--	2.34	5.47	6.08	36.8	36	23.1	29.8	48.6
BCAA	--	--	--	--	--	--	--	--	--	--	0.9	2.14	2.06	--	--	--	--	--
DBAA	--	--	--	--	--	--	--	--	--	--	0.79	3.25	2.81	--	--	--	--	--
TCAA	--	--	--	--	--	--	--	--	--	--	1.61	0.74	2.03	55.8	33.9	40.4	33.1	42

Table S7 Raw data for Figure 4, cytotoxicity.

	Percent of total cytotoxicity from DBAN without HAcAms included	Percent of total cytotoxicity from DBAN including HAcAms	Error for Data with HAcAms included	Error for data with replicated sampling events
167 BV, GAC WW with Calgon F400	66.11%	33.4%	8.94%	
2747 BV, GAC WW with Calgon F400	56.93%	44.9%	6.05%	
167 BV, GAC 10:90 WW:SW with Calgon F400	99.21%	50.1%	13.42%	0.08%
Krasner et al. 167 BV, GAC REPLICATE of blend with calgon F400	99.04%	40.1%	12.25%	
2747 BV, GAC 10:90 WW:SW with Calgon F400	69.43%	45.8%	9.20%	2.45%
Krasner et al. 2747 BV, DUP 10:90 calgon	74.32%	49.3%	9.83%	
167 BV, GAC 10:90 WW:SW with Norit HD3000	99.03%	47.1%	13.16%	
2147BV, GAC 10:90 WW:SW with Norit HD3000	72.10%	55.2%	8.14%	
167 BV, SW, with Calgon F400	99.03%	35.9%	11.49%	
2747 BV, SW, with Calgon F400	76.83%	48.9%	10.35%	
Pre-ozonated GAC	77.14%	46.1%	10.57%	17.6%
Pre-ozonated GAC	42.46%	30.3%	5.30%	
Pre-ozonated GAC	37.42%	27.6%	4.48%	
GAC	81.65%	46.0%	11.22%	2.6%
GAC	84.14%	46.8%	11.56%	
GAC	89.23%	48.3%	12.23%	
GAC	87.47%	47.8%	12.00%	
GAC	84.29%	46.9%	11.58%	
Pilot 2015	42.84%	39.5%	1.96%	
Pilot 2016	31.36%	28.7%	1.54%	
WTP A 5600 BV	9.04%	5.5%	1.18%	
WTP A 22400 BV	8.13%	5.2%	1.05%	
WTP B 3000 BV	20.31%	16.4%	1.88%	
WTP B 22000 BV	18.67%	16.3%	1.29%	

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